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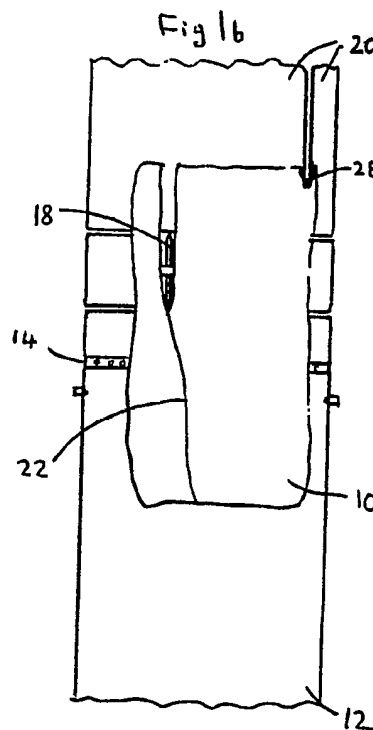
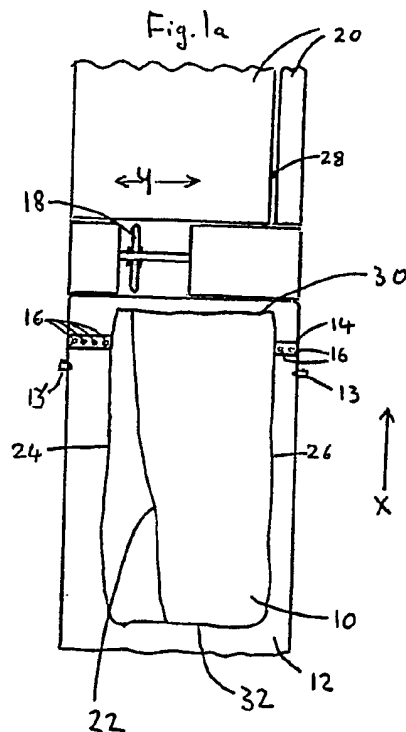
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## (54) Grading and quality control of meat cuts

(57) Meat cuts (10) conveyed along a path (12) are automatically assessed. Data from images and thickness measurements allow creation of 'volume maps'. Data from monitoring the attenuation of penetrative radiation (14, 16) such as X-rays enable creation of 'density maps'. The volume and density data may be used to determine weight data. The data may also be used to derive fatness data. Derived data (fatness and/or weights) can be used for control of subsequent treatment e.g. automatic cutting (18) and/or routing (on conveyors 20).



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A GRADING AND QUALITY CONTROL SYSTEM FOR MEAT CUTS

5 This invention relates to the grading and quality control of meat cuts. It also relates to the preparation or division of the meat cuts themselves.

10 The meat industry is gradually moving away from a craft-based, labour-intensive industry to one in which automation is increasingly playing a role. As a food that is perceived by the consumer as high value, and perhaps even to some extent a luxury, the quality of meat and meat products is expected to be high and consistent. There is, therefore a real and growing demand for systems that can dispense as much as possible with skilled operatives undertaking essentially repetitive jobs and replace them with increased throughput achieved by increased automation. 15 Unfortunately, the increase in throughput is all too often accompanied by a decrease in the control and assurance of quality, both in absolute terms and in variation around the ideal.

20 A quality criterion that is considered essential in all areas of the meat industry is weight. This applies throughout the chain that extends from the live animal on the farm to the cooked meat on the plate. Nevertheless, the requirement to weigh a cut of meat, perhaps at various stages as it progresses through a meat plant, is 25 inconvenient, and frequently a rate limiting step. Weight is often also a criterion (perhaps the sole criterion) in the allocation of an individual meat cut to a category or

class and is therefore inevitably tied up with quality control. Variability in weight of a carcass or cut within a quality category may contribute to the total costs associated with the corresponding meat cut or meat product, 5 for example with heavier cuts requiring a greater degree of trimming of fat than lighter cuts. On-line determination of the weight of an individual meat cut is therefore highly desirable.

For a variety of reasons, the value of meat is not 10 constant across all of the carcass; meat from certain anatomical locations commands a high price while meat from other locations is worth considerably less. In many regards the commercially successful traditional butcher chooses his division of a carcass into cuts of different 15 categories to maximise the relative proportion of high value cuts. Butchery of this nature requires training, experience, and time; three factors that are not always compatible with the high throughput demanded by today's industry. Labour turnover is also high in this industry.

20 The present invention uses the collection of data on the three-dimensional shape of a meat cut and the variation in density of that meat cut to provide a value for the weight of the meat cut. Since the major determinant of variability in density of meat (given a defined thickness 25 of meat cut, and ignoring bone) is the fat-to-lean ratio, and since fatness is also a quality characteristic, monitoring of density can also provide data suitable for fatness-related quality control. Further, in addition to

providing weight values and the ability to grade meat cuts on fatness, the provision of sub-surface information could facilitate the control of automated cutting machinery to a degree of precision previously  
5 impossible at the speed required.

According to one aspect of the present invention there is provided a method for the on-line determination of the weight of a meat cut comprising

(a) obtaining incremental thickness measurements  
10 of the meat cut;

(b) obtaining a representative image or images of the meat cut as viewed in the direction of the thickness measurements;

(c) processing the representative image or  
15 images to produce data on the area of meat portrayed in the image or images;

(d) exposing the meat cut to irradiation from a source of penetrative rays;

(e) assessing the amount of penetrative rays  
20 passing through the meat cut at a plurality of locations;

(f) processing the data obtained at step (e) to estimate density of the meat cut at a plurality of locations; and

25 (g) combining the data on density with the data obtained at step (a) and produced at step (c) so as to provide data relating to the weight of the meat cut or part thereof. For example, weights of successive

"slices" or portions of the meat cut can be determined, and these may be added together to provide the weight of the whole or a selected part.

The representative image or images is or are  
5 preferably obtained using a video camera. The  
preferred

penetrative rays are X-rays or ultrasound, most preferably X-rays.

Another aspect of the present invention provides a method for on-line quality control grading of meat cuts.  
5 This method comprises steps (a)-(e) and optionally either (f) or (f) and (g) of the method described above, and the additional step

(h) combining the data obtained or produced in steps (a)-(e) and optionally either (f) or (f) and (g) to provide  
10 a fatness value suitable for categorising the cut.

In another aspect of the present invention there is provided a method for directing the further dividing of a meat cut comprising the steps (a)-(e), and optionally either (f) or (f) and (g), of the method for determining  
15 the weight of a meat cut described above, and the further step

(i) processing the data obtained in the foregoing steps in a data processor, and using the processed data to direct a cutting means to subdivide the meat cut.

20 In any of the preceding aspects, the amount of penetrative rays scattered and/or diffracted by the meat cut may be assessed at step (e), as an alternative to assessing the amount of penetrative rays passing through the meat cut.

25 A further aspect of the present invention provides a flexible system that allows for the on-line determination of weight, and the on-line assessment of quality based on fatness value, and subdividing the cut, the system

comprising

(a) means for obtaining a representative image or images;

(b) a source of penetrative radiation;

5 (c) means for detecting said penetrative radiation;

(d) means for obtaining incremental thickness values for a meat cut;

(e) image processing means; and

(f) data processing means for interrelating the values  
10 obtained from the incremental thickness determination, the representative image or images, and the level of penetrative radiation reaching the radiation detecting means. Optionally, the data processing means are also able to direct the action of a cutting means.

15 The various aspects of the invention will now be described in more detail and with reference to Figs. 1a and 1b which are plan views of an embodiment of the invention at different stages of subdividing a belly of bacon.

Example 1 Subdivision of bacon bellies

20 In Figure 1a, a bacon belly 10 (that is a pork loin from which the loin muscle and associated tissue has been removed) is seen on a belt 12 which is moving in direction shown by the arrow X. Part of bacon belly is shown as having 10 already passed over X-ray detecting means 14,  
25 which comprises a plurality of X-ray sensitive diodes 16 (shown figuratively only; there may be of the order of 1,000 such diodes on a 0.45mm pitch). A video camera, positioned so as to be able to obtain a view similar to the

one portrayed in Figure 1a is triggered by bacon belly 10 breaking the light beam between photoelectric cells 13, 13'.

5 The original image captured by the camera includes inconsequential background as well as the image of bacon belly 10; the triggering of the camera facilitates locating the position of the representative image of bacon belly 10 within the original image. The position may also be determined by reference to a fixed  
10 point within the original image. Both line-store and frame-store video cameras are suitable for obtaining the representative image.

An X-ray source (not shown) is used to irradiate bacon belly 10 as it moves along the belt 12. As the tissue of  
15 bacon belly 10 passes over the X-ray detecting means 14, X-rays produced from the source are absorbed by that tissue, and the resulting attenuation of signal is detected by the X-ray sensitive diodes 16 as a diminution in signal. The intensity of the signal produced depends upon the thickness  
20 of the tissue of belly 10 as it passes over the X-ray sensing means 14, and the composition of that tissue. Conversion factors are available which can accurately relate the attenuation of the X-ray signal to the composition of the tissue passing over X-ray detecting  
25 means 14.

Since the information coming from the array of X-ray sensitive diodes 16 can be updated several hundred times per second, a very detailed "map" of the distribution of

tissue throughout bacon belly 10 can be built up; this "map" may be referred to as a "density map". Given the information on the area of the belly 10 that can be obtained from the representative image obtained by the video camera data on depth of the bacon cut at several locations, a comparable three-dimensional "map" of the shape of the cut is also obtainable; we can refer to this as a "volume map". By relating the volume map to the density map, the weight of the cut may be estimated.

Suitable means for obtaining sufficiently sensitive data on depth of belly 10 include "passive" methods such as laser lines, infra-red beams, or a calibrated video camera, or "active" mechanical means such as displacement of linear displacement transducers (LDT's) or similar devices.

In this example, a blade 18 of a rotary saw is located downstream from the X-ray detecting means 14. The blade 18 of the saw is driven at constant speed, and is movable backwards and forwards in the direction shown by the arrow Y under the control of a computer. As the belly 10 moves from belt 12 to split-belt 20 the computer directs the cutting action of blade 18 along the fat-to-lean interface 22 of the belly 10. The control is effected primarily through the information obtained from the overhead video camera, with an enhanced precision of separation obtained from the subsurface information on fat-to-lean ratio obtained from the X-ray detecting means 14. It will be appreciated that the greater precision of location of subdivision of the cut, based on sub-surface tissue

compositions, affords a more effective subdivision, maximising the weight of the higher value part of the loin, thereby increasing overall economic margin without affecting throughput adversely.

5           In the example illustrated in Fig. 1, the rotary blade has freedom of movement in the direction Y and is able to be tilted relative to this direction. This requirement for movement will normally require a discontinuity in the conveying belt. Directable cutting means (such as water  
10   jet- or laser-cutters) can also be used in association with a metal mesh-type conveying belt; obviating the necessity for a split belt.

          The subsurface information obtained from the density map also permits the accurate automated trimming of the fat  
15   layer from the underside of bacon belly 10. This could be effected, for example, by adjusting the cutting height of an apparatus similar to those used for removing rind from cuts of meat, which removes the fat layer as a sheet in a plane-like action. Alternatively, a layer of lean may be  
20   removed from the upperside of bacon belly 10 by suitable adjustment of the cutting height. Either action will be undertaken according to prevailing economic considerations, the former removal of the fat layer being preferred when lean bellies command a premium, the latter removal of the  
25   lean layer being chosen when lean trim is required. The cost-effectiveness of this choice is facilitated by the ability of the present invention to discriminate the depth of the appropriate layer to be removed on the basis of the

subsurface information, by relating the density information to depth of fat and lean layers previously obtained and stored in a database.

5 With suitable alterations, this application of the invention may be modified to trim one or both of the edges 24, 26 of the belly 10; this is illustrated in Fig. 1 for trimming edge 26 by blade 28 of a bandsaw, in this case fixed. The faces 30, 32 may be similarly trimmed. Trimming in this manner is often a necessary but labour-  
10 intensive operation and one that is required to maximise yield of saleable slices of bacon, the ideal being to convert an inconveniently and irregularly shaped cut of meat into a manageable slab, and its automation is clearly desirable. Present machinery is only partly successful, as  
15 it cannot respond to the differences that exist in the cuts from different animals. It is, of course, possible to combine such trimming with subdividing the belly.

#### Example 2 Boning of pork middles

Identification and location of specific meat components  
20 enables automation systems to separate these components with improved accuracy, reduced variability and greater cost effectiveness than is achievable with current manual operations. The boning of pork middles is one example where the present invention may be applied to automated  
25 deboning and hierarchical subdivision of cuts.

In a similar manner to that described for Example 1, a video camera is triggered to obtain a representative image of a pork middle by that pork middle breaking a light

beam between suitably placed photoelectric cells. Data on the depth of the pork middle are obtained. The principal bones are located as areas opaque to the penetrative radiation, for example X-ray or ultrasound. From these data, the optimum location for separating the loin from the belly is determined, and the middle is suitably divided into these two cuts. The loin and the belly are now directed along separate paths.

The separated loin passes through a similar system to that just described, and a representative image is obtained. The relative location of the individual bones of the ribs and backbone are determined. The bones are then removed by a suitable cutting means under the control of a computer. It will be appreciated that the degree of control can be chosen largely on the basis of economics: maximum yield (which is achieved when the bones are removed with little or no meat attached to them) is achievable through the combined use of flexible robotic arms able to move in all directions relative to the joint of meat under the control of a relatively powerful computer directing the cut according to the specific details of that joint; or a less sophisticated system, in which the cuts are effectively two-dimensional and directed by reference to a database derived from many other three-dimensional analyses of other pork middles, may be satisfactory under normal conditions. Loins of pork boned in this way may be further processed as shown, for example, in patent application PCT/GB93/01398.

Similar considerations apply to the treatment of the

pork belly. As before, the bones may be removed by a combination of flexible robotics and powerful computing to achieve maximum yield, or more optimally by automated "two-dimensional" cuts by reference to a database. The  
5 separated boneless belly can now be further processed as outlined in Example 1.

Example 3 Measurement of fat and lean in meat cuts and pieces

This Example illustrates the application of the  
10 invention to the continuous determination of fat and lean content of smaller cuts of meat by means of a sub-surface measurement system using X-ray attenuation. Meat pieces so assessed may then be selected for further processing according to their lean content. This selection may be  
15 enhanced further by the inclusion of certain quality attributes, such as colour or other attributes of appearance which may be obtained directly from the representative image obtained by the video camera.

It is possible to design a suitable system based on a  
20 moving belt such as that already described in Examples 1 and 2, but some difficulty may be experienced in obtaining sufficiently sensitive information on depth of the individual meat pieces, although it is perfectly suitable for such things as meat patties, burgers, stacks of sliced  
25 meats, etc, where any variability in thickness falls within reasonable limits. The accuracy of the fat/lean measurement of small and irregular pieces of meat can be significantly improved by packing the meat pieces together

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into a "block" having a constant depth and cross sectional area. The accuracy of measurement may be further improved by removal of the air between the meat pieces. Both these requirements can be achieved in the following manner: the meat pieces are fed to a hopper of a continuous vacuum pump and are pumped along a metal pipe. A length of this pipe has a rectangular cross section, provided with suitable "windows" for irradiating the meat mass with penetrative radiation. At the other side of the length of rectangular pipe are located the ray detecting means, and the fat to lean ratio is determined by the attenuation in signal.

In this Example, the incremental thickness values are obviously directly proportional to the flow rate of the meat mass, since the cross sectional area (and therefore the thickness) is fixed.

The system described in this Example may be used in a variety of ways. For example, it can be used to determine the efficiency of preceding operations such as material selection, butchery and boning. When combined with the measurement of meat quality attributes, it can also be used to measure the effectiveness of preceding operations such as pre-slaughter handling (eg. through the occurrence of dark-cutting meat), the slaughter operation itself (eg. incidence of meat that is pale, soft, and exudative (pse), or blood splash), carcass refrigeration, etc. These data can be used to inform and/or monitor and/or control operations preceding or following the measurement of fat and lean. The system could also be used to measure the

efficiency of further processing operations such as blending and mixing, by measuring the range and magnitude of the variability in fat content. The efficiency of such operations can also be improved by such a system, for  
5 example by optimising the sorting and subsequent mixing of the component materials.

In all of these Examples, the system may also be adapted to include a quality control component to detect extraneous particles, such as residual bone particles or  
10 metal.

CLAIMS

1. A method for automatic on-line assessment of meat cuts comprising, for each successive meat cut,

(a) obtaining incremental thickness measurements  
5 of the meat cut;

(b) obtaining a representative image or images of the meat cut as viewed in the direction of the thickness measurements;

(c) processing the representative image or  
10 images to produce data on the area of meat portrayed in the image or images;

(d) exposing the meat cut to irradiation from a source of penetrative rays;

(e) assessing the amount of penetrative rays  
15 passing through the meat cut or scattered and/or diffracted by the meat cut at a plurality of locations;

(f) processing the data obtained at step (e) to estimate density of the meat cut at a plurality of  
20 locations; and if data relating to weight are required,

(g) combining the data on density with the data obtained at step (a) and produced at step (c) so as to provide data relating to the weight of the meat cut or  
25 part thereof; and optionally

(h) combining the data obtained or produced in steps (a)-(e) and optionally either (f) or (f) and (g) to provide a fatness value suitable for categorising

the cut.

2. A method according to claim 1 which is adapted for the determination of the weight of meat cuts or parts thereof, and which comprises steps (a) to (g).

3. A method according to claim 1 which is adapted for on-line quality control grading, and which includes step (h).

4. A method for directing the further dividing of a meat cut comprising the method of any preceding claim and the further step:

(i) processing the data obtained in the foregoing steps in a data processor, and using the processed data to direct a cutting means to subdivide the meat cut.

5. Apparatus for the on-line determination of weight, and/or the on-line assessment of quality based on fatness value, of meat cuts or parts thereof, said apparatus comprising:

(a) means for conveying meat cuts along a path

(b) means for obtaining a representative image or images of a meat cut or part on said path;

(c) a source of penetrative radiation disposed adjacent said path and arranged to direct radiation into the path so as to impinge on a meat cut on said path in the thickness direction of said cut;

(d) means for detecting said penetrative radiation after interaction with a said cut;

(e) means for obtaining incremental thickness values for a meat cut;

(f) image processing means; and

5 (g) data processing means for interrelating the values obtained from the incremental thickness determination, the representative image or images, and the level of penetrative radiation reaching the radiation detecting means.

10 6. Apparatus according to claim 5 further including cutting means, and wherein the data processing means are arranged to direct the action of said cutting means.

15 7. A method or apparatus according to any preceding claim wherein, in operation, the assessment of the amount of penetrative radiation is used to construct a density map of the meat cut or part thereof.

20 8. A method or apparatus for the on-line assessment of meat cuts substantially as any herein described with reference to and as illustrated in the accompanying drawings.



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Claims searched: All

Examiner: R S Clark  
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**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK CI (Ed.N): G1A (ABAG, ABAX)

Int CI (Ed.6): G01N 33/02, 33/12

Other: Online: WPI

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
	None	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.